AMMONOTHERMAL METHOD FOR GROWTH OF BULK GALLIUM NITRIDE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. application Ser. No. 12/556,558 filed Sep. 9, 2009; which application claimed priority from U.S. Provisional Application No. 61/096,304 filed Sep. 11, 2008; and U.S. Provisional Application No. 61/178,460 filed May 14, 2009, commonly assigned, each of which is incorporated by reference in their entirety herein. This application is related to U.S. patent application Ser. No. 12/556,562 filed Sep. 9, 2009, commonly assigned, and which is incorporated by reference in its entirety herein.

BACKGROUND OF THE INVENTION

The present invention relates generally to crystalline materials. More particularly, the present invention provides a seed crystal and method using back and front side deposition of crystalline materials, e.g., GaN, AlN, InN. In a specific embodiment, the seed crystals can be used in an ammonothermal growth process or the like. Merely by way of example, the present substrate materials can be used in applications such as such as light emitting diodes, integrated circuits, MEMS, medical devices, combination of these, among others.

Single-crystal gallium nitride (GaN) containing compounds and related alloy compounds containing aluminum and indium (AlN, $Al_xGa_{1-x}N$, InN, $In_xGa_{1-x}N$) are useful semiconducting materials. Such semiconductor materials can be useful for a variety of applications due to their large bandgap and high chemical and thermal stability. In recent years there has been significant technological advancement in electronic and optoelectronic devices based on these materials, such as transistors, solar cells, light-emitting diodes, and lasers, among others. Although some of these products are available in the commercial market today, lack of a suitable GaN substrate on which to grow these materials remains a limitation to both performance and providing low cost, volume production of devices.

Conventional approaches to growth of GaN, AlN or InN containing compounds (collectively referred to as "(Al,In) GaN" compounds) and devices employ foreign substrate materials (containing one or more primary chemical species which is different from Ga, Al, In, or N), a process known as "heteroepitaxy". Heteroepitaxial approaches to growth of (Al,In)GaN containing compounds result in epitaxial films with high defect densities due to the large lattice mismatch, chemical dissimilarity and thermal expansion coefficient difference between the nitride materials and substrate. The presence of defects is well-known to be detrimental to device performance. The thermal expansion coefficient difference between the substrate and the epitaxial layer in heteroepitaxy results in strain gradients in the material which can lead to wafer curvature, referred to as bow or warp, after growth. As used herein, the terms bow and warp are used in a manner which is well understood in this art. Definitions, for example, can be found from SEMI (www.semi.org), but can be others commonly known. There is therefore a need for bulk GaN substrates of high crystalline quality, ideally cut from large volume bulk GaN ingots.

Ammonothermal growth is a promising low cost and potentially highly scalable approach to produce such a GaN ingot. Ammonothermal growth has provided high quality crystalline material. Unfortunately, drawbacks exist. As an example, ammonothermal growth techniques lead to small sized crystals, which are often not useful for commercial applications. Additionally, defects in the seed material used for ammonothermal growth often replicate on any grown crystal structures. These and other limitations often exist with conventional ammonothermal techniques.

From the above, it is seen that techniques for improving crystal growth are highly desired.

BRIEF SUMMARY OF THE INVENTION

According to the present invention, techniques for manufacture of crystalline materials are described. More particularly, the present invention provides a seed crystal and method using back and front side deposition of crystalline materials, e.g., GaN, AlN, InN. In a specific embodiment, the seed crystals can be used in an ammonothermal growth process or the like. Merely by way of example, the present substrate materials can be used in applications such as such as light emitting diodes, integrated circuits, MEMS, medical devices, combination of these, among others.

In a specific embodiment, the present invention provides a high quality gallium containing seed crystal having a large area that is substantially flat and free of bowing and/or bending. Of course, there can be other variations, modifications, and alternatives.

In a specific embodiment, the present invention provides a method for fabricating crystalline material, e.g., GaN. The method includes providing a crystalline substrate material having a first surface and a second surface. The method maintains the crystalline substrate material by engaging the second surface while exposing the first surface. In a specific embodiment, the method includes forming a first thickness of first crystalline material overlying the first surface of the crystalline substrate material. In a preferred embodiment, the first thickness of first crystalline material has a first orientation. In a specific embodiment, the method also includes providing the crystalline substrate material having the overlying first crystalline material and exposing the second surface of the crystalline substrate material. The method includes forming a second thickness of second crystalline material overlying the second surface of the crystalline substrate material such that the second thickness of second crystalline material has substantially a same thickness as the first thickness of first crystalline material. In a specific embodiment, the first thickness and second thickness comprise substantially similar composition. In this embodiment a substantially similar composition refers to the lattice constants of the primary constituent material within the first thickness and the primary constituent material within the second thickness being within about 0.01 Å. In another embodiment, the compositions of the first crystalline material and the second crystalline material are different but the lattice constant of the two materials are substantially the same being with about 0.05 Å of each other. In a preferred embodiment, the second thickness of second crystalline material has a second orientation. In a specific embodiment, both the first thickness and second thickness have epitaxial relationships with the crystalline substrate material.

One or more benefits may be achieved using one or more of the specific embodiments. As an example, the present device and method provides a substantially flat and large area seed crystal having high quality suitable for an ammonothermal or like process of crystal growth. In a specific embodiment, the present method and device can be made using conventional techniques and is cost effective. Depending upon the embodiment, one or more of these benefits can be achieved. These